TA01 - FY19
9/17/18

Council Requests for Additional Information from the Adminstration:

5. *Please provide a list of all the scenarios considered with the following information for each scenario:*
    a. *a summary/description;*
    b. *the total estimated cost;*
    c. *the flood mitigation impact achieved;*
    d. *any road closures necessary to construct/implement (including locations and durations); and*
    e. *your evaluation of the pros & cons.*

    Please see the attached Memo from Mark De Luca.

6. *Please provide clarification on what the plan is now -- which projects are actually included and which are still being evaluated.*

    Please see the attached Memo from Mark De Luca.

10. *Looking at the various studies over time, please compile a list of all the recommendations from all the studies and, for each recommendation, indicate whether or not it is incorporated into the proposed plan and explain why.*

    Please see the attached Memo from Mark De Luca.

12. *What will this plan actually address and achieve? Can we quantify the impact of executing this plan in accomplishing a specific amount of flood mitigation?*

    Please see the attached Memo from Mark De Luca.

Howard County
Internal Memorandum

SUBJECT: Council Information Request

TO: Caryn Lasser

FROM: Mark De Luca

DATE: September 17, 2018

In response to the Council's request for more information please find the attached.

Specifically, their request as listed:

5. Please provide a list of all the scenarios considered with the following information
   a. a summary/description
   b. the total estimated cost
   c. the flood mitigation impact achieved
   d. any road closures necessary
   e. your evaluation of the pros and cons

10. Looking at the various studies over time, please compile a list of all the recommendations from all studies and, for each recommendation, indicate whether or not it is incorporated into the proposed plan and explain why.

The attached spreadsheets and report texts are offered to answer these two questions.

For Question 6, the 5-year plan consists of:

1. Ellicott City Property Acquisition/Removal
2. Lower Main Street Open Space Construction
3. Ellicott Mill Culvert Expansion
4. The Hudson Bend
5. Frederick Road Culvert Improvements
6. Church/Emory Streets Storm Drain Improvements.
7. Quaker Mill Retention Facility at Rogers Avenue
8. Hudson 7 Retention Facility at US 29/Rt. 40 Interchange
9. New Cut Road Slope Failure
10. Maryland Avenue Culverts

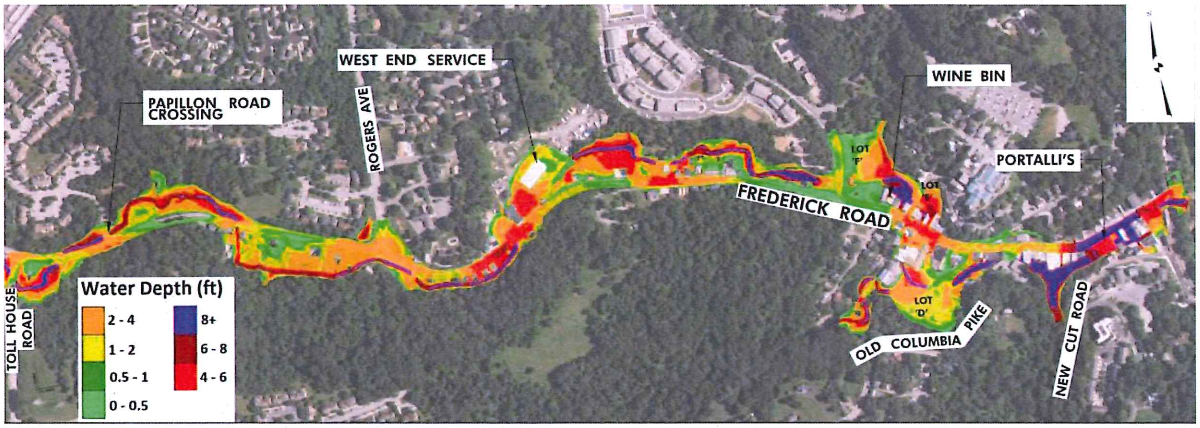
Listed below is an anticipated schedule for the work.

Projects	FY 19	FY 20	FY 21	FY 22	FY23
Acquisition/Building Removal					
Lower Main	X				
Middle Main			X	X	
West End	X	X	X		
Lower Main Open Space					
Design	X				
Construction	X	X			
Ellicott Mills Drive					
Design	X				
Construction	X	X			
Hudson Bend					
Design	X	X			
Construction Phase I			X	X	
Construction Phase II				X	X
Frederick Road Culvert Expansions					
8600 Block					
Design/Permitting	X				
Construction	X	X			
8700/8500 Block					
Design		X			
Construction			X		
Church St/Emory Street Drainage					
Design	X				
Construction		X			
Quaker Mill Flood Control Facility					
Design/Permitting	X	X			
Construction		X			
H7 Flood Control Facility					
Design/Permitting	X	X			
Construction			X		
New Cut Road					
Design	X				
Construction		X			
Maryland Avenue Culverts					
Design		X			
Construction			X		

The retention facilities T-1 and NC-3 are still being evaluated at this time.

For Question 12, What will this plan actually address and achieve? Can we quantify the impact of executing this plan in accomplishing a specific amount of flood mitigation?

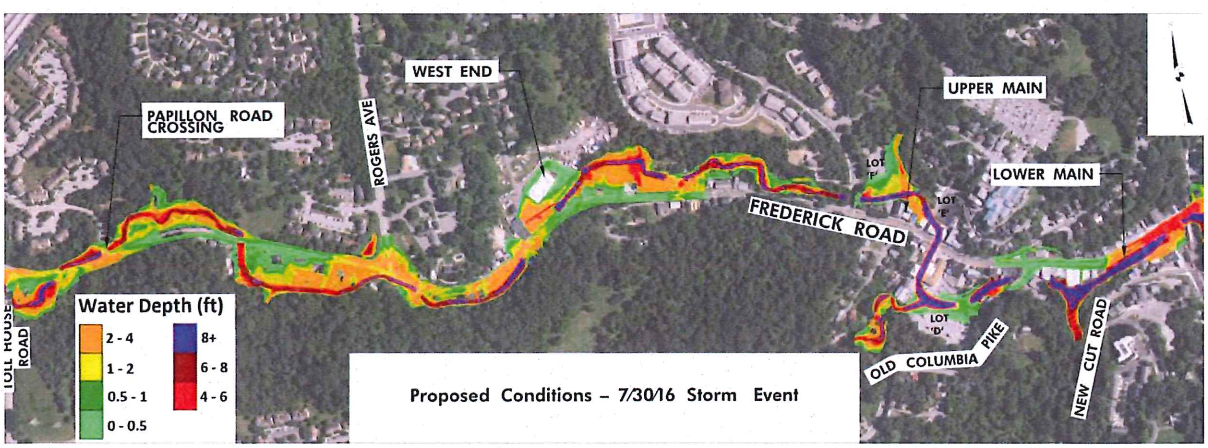
Modeling of the July 30, 2016 storm indicated 6 to more than 8 feet of water on lower Main Street. Water velocities were greater than 20 feet per second (fps) with induced shear forces greater than 15 pounds per square foot (psf). On the West Main Street, 4 to 6 feet of water was on the street, and many flooded homes were on the north side.



After completion of the 5-year plan projects, Lower Main Street water levels drop to 4 to 6 feet. This water level approaches acceptable water elevations for floodproofing. Velocities drop to 4.5 to 6.5 fps.

On West Main Street, flood waters are more easily contained in the channel. Water on the road is expected to be as low as 0.5 feet in some areas but there may be some pockets of 2 to 4 feet. Repeated damage to residences on the north side will decrease significantly.

Recommended Mitigation Improvements Model



McCormick Taylor 2011 Study

Project	Summary/Description Flood Mitigation Impact Achieved	Total Estimated Cost	Notes
Retention Facility H-7	**See attached McCormick Taylor Study dated April 3, 2014, pgs 30 thru 41**	$5.0M	Located within the 29/40 interchange
Alternate 4 Storm Drain		$2.0M	Part of the **Rogers Avenue Storm Drain Improvement Project**
Alternate 5 Storm Drain		$1.0M	Private property Not considered but now part of the 5-yr plan and acquisition and renamed **Frederick Road Culverts**
Alternate 6 Storm Drain and Alternate 7 Channel Structure Modifications		$20M	Now refered to as the **Hudson Bend**

S&S Consultants 2012 Case Study

8700 Address Zone	**See attached S&S Study dated June, 28, 2012, pgs 8 thru 16**	see above	Included in **Frederick Road Culvert Replacements** mentioned above
8600 Address Zone		see above	A portion is addressed under the **Rogers Avenue Storm Drain Improvements** and also under the **8600 Main Street Culvert Expansion**
8500 Address Zone		see above	Included in the **Frederick Road Culvert Replacements**
8300 Address Zone		see above	Improvements renamed **The Hudson Bend**
8100 & 8000 Address Zone		$4.6M	Improvements renamed **Lower Main Open Space**

McCormick Taylor 2016 Study

Project	Summary/Description Flood Mitigation Impact Achieved	Total Estimated Cost	Notes
Tiber 1 Retention Facility		$20M	**Known as T-1**, this is being evaluated as a P3
New Cut Retention Facilities NC-1 thru NC-4	**See attached McCormick Taylor Study dated June 16, 2016, pgs 24 Thru 42**	$10M	**Known as NC-3**, in preliminary design. Only NC 3 pursued as most cost effective for first round construction
Hudson Retention Facilities H-2 thru H-7		See Above	**Known as H-7**. Only H-7 pursued as most cost effective for first round construction
Underground Storage Facilities H-1 thru UG 1-3		N/A	None pursued in first round because of high rock excavation costs and an low storage capacity
Conveyance Improvements		See Above	All conveyance improvements are now included and listed as **Frederick Road Culvert Improvements**
84" to 108" Culvert Replacement		$1.6M	Listed as **8600 Main Street Culvert Expansion**
Tunnel Bore Improvements		$150M	Cost, constructabiliy and performance issues resulted in option not being considered

McCormick Taylor Modeling Post May 27th, 2018

(considers removing Lower Main properties and West End properties)

Option	Terraced Floodplain	Modified Floodplain	Quaker Mill	Lot D Expand	T-1	H-7	NC-3	MD Ave Culverts	Tailwater	West End Improve	Notes
1	*										Only removes 5 bldgs in floodplain
2	*										FP grading w/piers
3	*										FP Facades only
4	*										Includes Ellicott Mills Improve
5	*		*			*					
5A	*	*tot, gp	*			*					
6	*		*	*		*					
7	*		*	*		*	*				
8	*		*	*	*	*					
9	*		*	*	*	*	*				
10	*			*				*			Conveyance option
11	*		*	*	*	*	*	*			C+SWM option
12	*	*tot, gp		*				*			C=Mod FP
13	*	*tot, gp	*	*	*	*	*	*			C+SWM+Mod FP
14	*	*tot, gp	*	*	*	*	*	*	*		
15	*	*tot, gp	*	*		*		* 2 pipes	*	*	
16	*	*C Lab	*	*		*		* 2 pipes	*	*	
16B	*	*C Lab	*	*		*		* 2 pipes	*	*	Adjusted Terracing
16C	*	*C Lab Purp	*	*		*		* 2 pipes	*	*	Current 5-year plan option
16D	*	*C Lab Purp	*	*	*	*		* 2 pipes	*	*	

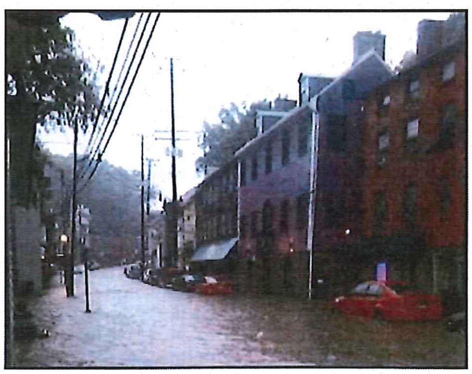
Ellicott City Flood Study
And
Concept Mitigation Report

Howard County
MARYLAND

McCormick Taylor Project No. 5493-01
April 3, 2014

Prepared for:

Howard County Government
Storm Water Management Division
Bureau of Environmental Services
6751 Columbia Gateway Drive, Suite 514
Columbia, Maryland 21046-3143



Prepared by:

McCORMICK TAYLOR

509 South Exeter Street, 4th Floor
Baltimore, Maryland 21202
(410) 662-7400

Frederick Rd. This overflow onto Frederick Rd. was simulated for all three storm events.

A lower flowrate of overflows entered Frederick Rd. from the driveway adjacent to Ellicott Mills Brewing Company. Flooding from this area originated at the open stream section at the south end of Parking Lot 'E'.

Flood waters from these areas continued down Frederick Road to the end of the modeled region. The 50- and 100-yr storms simulated significant flowrates down the roadway. The depths of flooding along Frederick Rd. was greatest between representative Cross Sections 'E' and 'F', and decreased as velocity down the roadway increased towards the intersection of Frederick Rd. and Old Columbia Pike. 100-yr roadway depth along representative Cross Section 'E' was approximately 4.1 ft and velocities between representative Cross Section 'F' and the intersection with Old Columbia Pike approached 35 ft/s; these flows were significantly less for the 10-yr storm, with a respective average roadway depth of 1.6 ft and velocities approaching 20 ft/s.

Significant flooding of Parking Lot 'D' was simulated for all three storm events. Flood waters in the parking lot had multiple origins depending on the storm event. For the 10-yr storm, flood waters originated almost entirely from the open stream section running through the parking lot, with some minimal flows coming down Forrest St. from Frederick Rd. The 50- and 100-yr events simulated flood waters entering Parking Lot 'D' from the open stream section, from Forrest St, and from overtop the culvert that confluences the Tiber Branch with Hudson Branch near the footbridge. Flooding from this open stream section is likely the result of backwatering from the footbridge and downstream culvert, as well as from the low channel depth (high bedrock depth) relative to the parking lot.

The extent of flooding in Parking Lot 'D' for the 50- and 100-yr events threatens the building at the northwest corner of the lot with a turbulent back eddy, while low velocity but high water surface elevations threaten several buildings at the east end of the lot. Flood depths along representative Cross Section 'F' vary greatly because of varying topography, significant elevation differences and differing flow paths. The most stable area for depth of flooding was in the overbank north of the open stream section, downstream from the footbridge. Flood depth in this location was 1.9 feet for the 10-yr model and 3.5 ft for the 100-yr model.

4.0 Conceptual Improvements

The study focused on two main types of conceptual improvements, stormwater quantity management to reduce the quantity of flow into the Main Street corridor, and conveyance improvements that would upgrade or supplement the storm drains and channels through the flooded area to carry more water at a lower elevation for a given event. Though there are a number of smaller stormwater improvements that could be implemented, the scope of this study was limited to the largest feasible sites that could have the most significant impact on the quantity of flow, as well as sites within public rights-of-way. The structure of the model created for this study allows for any variation on, or combination of, improvements to be run through the model at a later date, however for the sake of keeping the large amount of data manageable, the focus of this study will include 3 improvement iterations: SWM Only, Conveyance Only, and All Improvements

4.1 DEVELOPMENT OF SWM SITES

The challenges in locating new sites to provide significant quantity management were numerous. Much of the watershed is built out with residential and commercial development, with the exception of some wooded areas on the periphery of the watershed. These areas are not suitable as they are in steep terrain, would involve significant tree loss, and most importantly do not receive much if any runoff from developed areas due to their upland location.

The most promising locations for storing and managing a significant volume of runoff were the areas within the US 40 / US 29 interchange, which are owned by Maryland State Highway Administration (MSHA). These areas are not currently utilized by MSHA for stormwater management, presumably because the interchange was built prior to the SWM era. The grading of the proposed facilities is conceptual and does not account for potential geotechnical or regulatory constraints such as the presence of bedrock and limitations imposed by MSHA (the property owner) or other regulatory agencies. Three areas were examined for their potential improvement:

SWM Area 1 – This is the northeast loop of the interchange and is online with the main channel that carries DA 1 and a portion of DA 2 under US 40 to the south. As a result, any management applied in this location will attenuate the flow from nearly the whole northern portion of the watershed (North of US 40) making it the most effective of all the sites. The storage would be created by excavating most of the area inside the loop down to near the elevation of the existing channel. Though online ponds are typically not encouraged by Maryland permitting agencies, exceptions can be made for specific circumstances such as this, particularly in light of the fact that fish passage does not currently exist at this location due to a 3' drop in a concrete structure at the entrance to the culvert under US 40. Because the pond storage created is in cut relative to surrounding areas, and outfalls into a storm drain system that does not daylight for over 900' from the pond, it would most likely not require any additional seepage control (Code 378 exempt).

SWM Area 2 – This area is in the lower half of the southeast interchange loop and collects runoff within DA 2 from a portion of US 40 and its ramps, as well as an unmanaged commercial area just to the east. The outfall spillway pipe, currently a culvert under the loop ramp to the south, would require retrofitting for seepage control in compliance with Code 378, which could be achieved for the existing ramp embankment with a clay liner on the upstream face to supplement the pipe replacement. The stage-discharge table is based on maintaining groundwater baseflow and maximizing storage / attenuation while maintaining over 2' of freeboard for the 100-year event.

SWM Area 3 – This area is in the over-widened median of US 29 in the southern portion of the interchange and receives runoff from the eastern portion of DA 3 including the currently managed areas in Ellicott Center, as well as portions of unmanaged commercial development and US 29 ramps. The outfall spillway pipe, currently a culvert under US 29 SB, would require retrofitting for seepage control in compliance with Code 378, which could be achieved for the existing roadway with a clay liner on the upstream face to supplement the pipe replacement. Alternately, a weir structure upstream of the existing US 29 culvert may allow for the culvert to remain as a non-378 spillway pipe in lieu of a pipe replacement under the roadway. Stage-discharge was developed under same principle as above.

An additional SWM area along US 40 WB, west of US 29 was initially investigated as a location to treat runoff from some of the western portion of DA 3, however it was discovered that this area is currently under development and not publically owned, therefore it was removed from further consideration

4.1.1 Analysis of the Effects of Proposed CWP SWM Improvements

As part of the overall analysis, the County provided a map prepared by the Center for Watershed Protection of potential SWM LID retrofit site locations within the area and requested that the potential impact of these proposed facilities on flooding-related runoff be included. Without additional information regarding the specific design or drainage area of these BMPs two assumptions were made: Sites would treat the first 1" of runoff back to "woods in good condition" per Environmental Site Design (ESD) criteria. Drainage areas were based on the most likely location of the actual BMP relative to existing roads and structures in the vicinity of the point shown.

The initial consideration of these sites was to see if the impact on runoff was significant enough to include in the overall analysis relative to the precision and error inherent within the model. A Curve Number (CN) reduction to "Woods – Good" was made for the presumed drainage area to each site and that was factored into the overall weighted CN for each DA and compared to the original to determine the effect of overall peak flow quantities. If the site locations fell within an area where existing SWM existed and was being modeled by CN reduction as discussed in Section 2.3 above, then this reduction was not made, since it had already been considered in existing conditions. Since the study includes storm events above the 1" runoff event considered for ESD design, the MDE methodology for Relative Curve Number (RCN) adjustment for determining the effect of ESD on higher storm events was used. For the sites in question, the change in CN for the 2-year event becomes numerically insignificant (<1%) for 7 of the 10 sites analyzed, with the largest change of 2.3% for a facility in DA 7.

Table 4.1 – Changed Runoff Curve Numbers for Proposed CWP Facilities

Subarea	Drainage Area	Original CN	CN w/ CWP Facilities				% change**
			2-yr	10-yr	50-yr	100-yr	
1	2	80.559	80.558				-0.001%
	3	75.926	75.925				-0.001%
2	1	88.594	87.960				-0.716%
3	4	82.378	82.079	82.147	82.178	82.196	-0.363%
	7	86.132	85.339	85.433	85.485	85.549	-0.921%
4	3	79.166	78.689				-0.603%
6	2	80.006	78.695				-1.639%
	3	79.468	79.383				-0.107%
	5	66.708	65.497				-1.815%
7	4	72.091	70.444				-2.285%

**% Change between the original CN and CN w/CWP Facilities for the 2-yr storm.

Since the RCN adjustment decreases for the higher (>2-year) storm events considered in this study, and the impact for even the most significantly changed sub-areas was a matter of a few cfs for the 2-year event, it was determined that the impact of these conceptual proposed ESD sites was not significant enough to show a change in water surface elevations within the models, and was not pursued in greater detail within this study. It is noted that, despite the negligible impact on larger flooding events, these potential facilities still have value relative to their collective positive impact on water quality in the Patapsco watershed during more frequent storm events.

Table 4.2 – Peak Discharges with and without Proposed CWP Facilities

Return Period (years)	Peak Flow (cfs) Entire Drainage Area, no CWP Facilities	Peak Flow (cfs) Entire Drainage Area, w/CWP Facilites	Peak Flow (cfs) Subarea 3, no CWP Facilities	Peak Flow (cfs) Subarea 3, w/CWP Facilities
2	535	530	242	240
10	1356	--	568	567
50	2647	--	1074	1072
100	3549	--	1331	1329

4.2 Development of Additional Conveyance Sites

In addition to examining alternatives to reduce the quantity of water to the Main Street corridor, the possibility of providing increased runoff conveyance capacity, in the form of additional storm drains and channel widening where feasible, was examined. These alternatives, numbered 4-7 sequentially after the 3 SWM alternatives, and from upstream to downstream, are described below (See *Appendix C* for storm drain layout maps):

Alternate 4 Storm Drain – This alternate consists of a 48" concrete storm drain trunk line that intercepts the runoff from the Rogers Ave. storm drain (the northern, developed portion of DA 6) and conveys this flow eastward separate from the Hudson Branch flow (DAs 1-5) running roughly parallel to the channel and culvert system currently carrying Hudson Branch, and outfalling at the existing culvert outfall location at the east end of the West End property into an open channel behind the adjacent residential properties (8578, 8572 Frederick Rd). This option would also involve abandoning the existing cross culvert that connects the Rogers Ave flow to the channel in current conditions. A flow splitter was considered here to balance the flow between the two systems, but the tailwater from the culvert and channel made the new proposed system largely ineffective at its upstream point for higher flows, so the proposed model keeps the systems separate.

The sizing of the pipe is based on tying in to the existing Rogers Ave system invert with adequate pipe cover, as well as what is reasonably feasible for construction given issues like trench width and depth while maintaining traffic as well as likely utility conflicts. The intent of this alternate is to reduce the frequency at which overtopping of channel flow from the south side onto Main Street will occur just downstream of Rogers Ave.

Alternate 5 Storm Drain – The location of the upstream entrance to this system is based on supplementing conveyance where the open channel flow goes back into a closed pipe system again, in this case the culvert between the structures at 8520 Frederick Rd. The storm drain will capture a portion of this channel flow and divert it back to the roadway, running parallel with the road before outfalling back into the channel at the point where the channel curves south then east to be immediately adjacent to the road. This location was selected because it is the point where the existing condition roadway flow that escaped from the channel upstream enters back into the channel, and can be adequately conveyed by the existing channel. The concept pipe sizing is based on similar constraints as described in Alternate 4, above. There are some local storm drain tie in issues associated with this alternate as well that would be examined during the detail design phase if this alternate is pursued.

Alternate 6 Storm Drain – The location of the upstream end of this system was selected to provide additional conveyance just upstream of the constrictions associated with the flow under Court Ave, the Ellicott Mills Brewing Company and the downstream conveyance under La Palapa Restaurant. The storm drain will capture a portion of the channel flow upstream of Court Ave and carry it south, under the driveway between 8344 and 8358 Frederick Rd., briefly east along Frederick Rd., south again down Merryman St. then east just behind La Palapa where it will outfall into the existing channel, recombining with the flow from the existing system. The concept pipe sizing is based on similar constraints as described in Alternate 4, above.

Alternate 7 Channel/Structure Modifications – For the final alternate, the channel through Parking Lot 'D' which carries the flow downstream of the confluence with Tiber Branch, the dimensions of this channel were modified to include a layback of the currently vertical slopes at a 3:1 cross slope. Also the structure that carries the flow beneath the northeast portion of the lot was raised by 2 feet to accommodate more flow. There are many permutations of widening and structure modifications, with varying impacts to the parking lot, that could be examined here; the one chosen was a typical iteration intended to examine whether or not such modifications had a significant impact on the tailwater and water surface of the upstream channel and systems along Main Street.

4.3 Modeling of Improvements

4.3.1 SWM Improvements

The SWM improvement alternates were modeled by developing a preliminary pond grading of each area, setting a weir elevation for flow above a base flow amount that would carry the 100-year storm with adequate (2'+) freeboard for overtopping at the lowest point, and calculating a stage-storage-discharge table to be inserted into the existing condition TR-20 model at the proper location. The proposed condition was modeled in TR-20 with all 3 alternates in place at once, and the resulting downstream hydrographs were used in the hydraulic model as a comparison against the baseline conditions.

4.3.2 Conveyance Improvements

The conveyance improvements were modeled differently for the HEC-RAS and TUFLOW models. For the HEC-RAS model, Concept 4 was included by reducing the inflow at cross section 37 by 60 cfs and then adding 60 cfs back into the model at the exit of culvert 4 at cross section 14. This flowrate was removed as it was calculated that 60 cfs was the approximate maximum capacity of the Concept 4 pipe given the existing constraints. A similar approach was taken for Concept 5, which diverts flow from the river at cross section 2. The flowrate removed from cross section 2 was determined by cross-referencing the water surface elevations from the existing model with the total head listed in the storm drain hydraulic design table (*Appendix C*). Following this methodology, flowrates of 100, 120, and 150 cfs were removed from cross section 2 for the 2-, 10-, and 100-yr storm events, respectively.

For the TUFLOW conveyance model, new culverts were added to the 1-D culvert network to represent concepts 5 and 6. Concept 7 was represented by generating a new topographic layer to augment the grading of the stream bank to a 3:1 slope. The culvert through Parking Lot 'E' was raised 2 ft by changing the existing culvert characteristics to reflect the new culvert dimensions. The hydrographs from the existing conditions hydrologic models were run through the proposed conditions models as a comparison against the baseline conditions.

4.3.3 Combined Improvements

For this iteration, the proposed hydrology with the 3 SWM alternatives was run through the proposed conditions hydraulic model with the 4 conveyance improvements to determine the combined effect of all concept improvements on water surface elevations

4.4 Modeling Results of Proposed Improvements

Changes to water surface elevations between the 2-, 5-, 10-, and 100-yr storm events in the 1-D modeling region are displayed on cross sections in *Appendix D.* Floodplain depth/extent and velocity maps of the existing and proposed conditions are in *Appendix E.*

4.4.1 Results of SWM Improvements

The proposed SWM improvements significantly reduced peak flows into the modeled watershed region (Table 4.3).

Table 4.3 – TR-20 Simulated Peak Flowrate to Watershed Outlet for Existing Conditions and the Proposed Stormwater Management Concept

Storm Event	*Peak Flowrate (cfs)*		*Percent Change*
	Existing Conditions	*Proposed SWM Concept*	
2-yr	535	460	-14.0%
10-yr	1356	1099	-19.0%
Tropical Storm Lee	2122	1800	-15.2%
50-yr	2647	2167	-18.1%
100-yr	3549	2740	-22.8%

The reduced flowrates under the proposed scenario resulted in decreased water surface elevations, flow velocities and the extent of the floodplain; the magnitude of the changes to these variables is dependent on the unique topographic features at any specific cross section in the modeled area. *It is important to note that percent peak flowrate reductions do not necessarily represent equivalent reductions in water surface elevation, flow velocity, or flood extent.*

Another metric used to evaluate impact of the proposed improvements was the number of buildings within the floodplain (Table 4.4). All buildings within the 2-D modeling boundary (approximately 8578 Frederick Rd. to the intersection of Frederick Rd. and Old Columbia Pike) that were touched by the floodplain were quantified for existing conditions and the proposed stormwater management concept. This comparison was only conducted for storm events evaluated with the 2-dimensional model.

Table 4.4 – Number of Buildings within the Floodplain under Existing Conditions and the Proposed Stormwater Management Concept

Storm Event	*Number of Buildings in Floodplain*		*Change*
	Existing Conditions	*Proposed SWM Concept*	
10-yr	40	39	-1
Tropical Storm Lee	47	45	-2
50-yr	58	47	-11
100-yr	66	60	-6

The HEC-RAS models of the existing 2- and 5-yr storm events simulated minimal overbank flooding; the proposed SWM model reduced these simulated water surface elevations even further, providing greater freeboard for overbank flooding.

The HEC-RAS SWM concept model of the 10-yr storm simulated reduced water surface elevations and eliminated existing overbank flooding from the upstream cross sections 40, and 28. The model of the SWM improvements still experiences significant backwatering from the 108" culvert downstream, which results in the culvert overtopping and roadway flooding for cross sections 27-24 for the 10-yr event. 10-yr HEC-RAS water surface elevations between the existing and proposed SWM models dropped by 1.0 ft or less for the 1-D section below the 108" culvert. Flood depths and overall roadway flooding is reduced through all cross sections for the 100-yr event, and simulated roadway flooding was eliminated for 2 of the 27 existing cross sections that exhibited roadway flooding in the HEC-RAS model.

TUFLOW modeling of the proposed SWM concepts simulated reduced flooding from all storm events. The changes between the existing conditions and proposed SWM models are evident in the floodplain extent shown on the maximum flood depth maps.

The SWM concepts reduced the maximum extent of flooding more for the 5-yr event than for the 10-yr storm event. The concepts reduced roadway flooding and flooding around dwellings in Area 4 and Areas 5 and 6 for the 5- yr storm event, while the 10-yr event showed the greatest reductions in the parking lot of La Palapa and County owned Parking Lots 'D', 'E', and 'F'. The SWM concept model reduced flood depths in the roadway at representative Cross Section 'E' by 0.66' and by 0.78' on the north overbank along representative Cross Section 'F'.

The Tropical Storm Lee event is included in the iterations to allow for readers of this report to see a comparison of the expected improvements against a recent memorable event. The effects of the proposed SWM improvements for the Tropical Storm Lee event are evident throughout the modeled area. Reductions in flood plain extent were fairly comparable throughout the modeled area. For this storm event, the greatest impacts resulting from the SWM improvements are largely depth of flow reductions in areas 3 and 4. This can be evidenced by the change in inundation level in and around the dwellings in these areas. The effects of SWM improvements on the Tropical Storm Lee event most closely resembled the SWM effects for the 10-yr storm event.

The simulated floodplain extent of the 50-yr storm decreased under the SWM Concept model because flows did not overtop the culvert flowing below Ellicott Mills Dr. Without overtopping this culvert, the floodplain from the SWM model did not expand nearly as far into Parking Lot 'F' and did not escape onto Frederick Rd. until the driveway just west of Court Ave.

The SWM concepts had the greatest impact on flood depths of the 100-yr storm, however, this had a minimal effect on the overall extent of flooding because all culverts were still overtopped and road banks were flooded in the same locations. The depths, velocities, and overall extent of flooding from the 100-yr SWM Concept model closely match those simulated for the existing 50-yr model because their peak flowrates are very similar.

4.4.2 Results of Conveyance Improvements

The proposed conveyance improvements had no impact on the total inflows to the model, thus all changes to the flow patterns were a direct result of the added storm drain structures. The HEC-RAS portion of the model was not greatly affected by inclusion of conveyance Concept 4; the water surface elevations of the 2- and 10-yr storms decreased by approximately 0.2 feet for the majority of the 1-D modeling region, while the 100-yr water surface only decreased by approximately 0.1 foot. For the cross sections immediately above the second large culvert (96") (cross sections 3 and 4), the water surface of the 2-yr event dropped approximately 1.3 ft under the storm drain concept model, while the 10-year water surface dropped 0.17 ft. and the 100-yr storm was negligibly impacted.

The TUFLOW model of conveyance concepts exhibited similar, negligible impacts on flooding for this upper section. The greatest effects of the storm drain concepts were simulated for the 10-yr event and are at representative Cross Section 'B', which is located immediately upstream of Concept 5. The addition of Concept 5 appears to reduce backwatering behind the 96" culvert, and reduces the water surface elevation in the channel by 0.6 ft, which was a greater reduction than was simulated for the SWM concept model. Floodplain water surfaces at representative Cross Section 'B' are negligibly impacted, indicating that the flooding relief of Concept 5 is localized and thus water is still escaping into the floodplain further upstream. In the heavily populated area where Concept 5 has diverted flow from the stream (8516 Frederick Rd. to 8450 Frederick Rd.), the overall extent of flooding appears slightly diminished for all storm events, as evidenced by the depth of flooding maps.

The results at representative Cross Section 'C' indicate that, for the 10-yr storm, Concept 5 had negligible impacts on water surface elevations downstream from where it reintroduces flow into Hudson Branch. For the 100-yr storm, Concept 5 redirected flow into the channel at representative Cross Section 'C', which eliminated the minimal flooding of the roadway and south overbank that had been simulated for the existing conditions model.

Concept 6, which diverted flow from west of Court Ave. to the open section in Parking Lot 'E', had conflicting effects on flooding of the downtown area between representative Cross Section 'D' and the intersection with Old Columbia Pike. The concept successfully diverted a portion of flow from the Frederick Rd. corridor, which reduced flood depths and velocities in the roadway and the flooding extent in parking lots along Frederick Rd. At representative Cross Section 'E', existing roadway flood depth was reduced by 0.5 ft by the 10-yr, storm drain model. Concept 6 also alleviated some flooding upstream of Court Ave. as evidenced at representative Cross Section 'D', where flood depth in the floodplain was decreased by 0.5 ft and 0.25 ft for the 10- and 100-yr storms, respectively.

Because Concept 6 diverted flow away from Frederick Rd. and into the stream channel in Parking Lot 'E', Parking Lot 'E' experienced increased flooding for all storm events. Concept 7 was designed to aid in the conveyance of flow through Parking Lot 'E', and it achieves this goal (see Concept Flow Comparisons, *Appendix C*), however, flood depth and flooding extent in Parking Lot 'E' still increases for the conveyance concept model. This is likely because the flow added to the stream from Concept 6 backwaters into the parking lot behind the footbridge.

Generally speaking, the reductions and effects of this concept for the Tropical Storm Lee event fall between the 10-year and 100-year events.

4.4.3 Results of Combined Improvements

The models showing the combined SWM and conveyance improvements simulated the greatest reductions in overbank flooding for all model areas except for Parking Lot 'E', where the SWM concept model simulated the least flooding.

The combined SWM and conveyance concepts HEC-RAS model simulated a cumulative effect on water surface elevations, however with only minimal reductions resulting from the conveyance improvements, the combined model water surface elevations were very similar to those of the SWM model. Compared to the existing model, the 100-yr water surface of the combined concepts model reached the roadway on 22 of 40 cross sections, which was four fewer than the existing condition model; three of the four cross sections where existing roadway flooding was eliminated were the same for both for the SWM and combined models.

Because the TUFLOW conveyance model did not greatly affect flood extents for the 50- and 100-yr storms, the TUFLOW combined model for these events is very similar to the SWM model. For the 5- and 10-yr storm events, the proportion of total flow manipulated through the storm drain concepts was substantial enough to alter overall flow patterns, thus the flooding extent of the combined model was most different from the SWM model for these storm events.

5- and 10-yr, existing water surface elevations were most substantially reduced with the combined TUFLOW model at representative Cross Sections 'D' and 'E'. At representative Cross Section 'D', the combined model reduced 10-yr, existing water surface elevations by nearly 2 ft in most areas. At representative Cross Section 'E', the 10-yr existing water surface elevations were reduced by 1.7 ft in the roadway and existing flooding of the parking lot at La Palapa was eliminated. In Parking Lot 'E', the combined model had slightly higher water surface elevations than the SWM model, however both models had similar flood extents within the Parking Lot; 10-yr existing roadway water surface elevations at representative Cross Section 'E' were 0.8 ft lower with the combined model than with the SWM model.

The greatest reductions in existing water surface elevations for the 100-yr event were simulated at representative Cross Sections 'A', 'B', and 'E'. In the south floodplain of representative Cross Section 'A' and in the channel of representative Cross Section 'B', existing water surface elevations dropped by 1.2 and 1.3 ft, respectively. At representative Cross Section 'E', existing flood elevation in Parking Lot 'E' decreased by 1.2 ft and by 1.1 ft in the roadway. Combined model flooding elevations in the channel and the immediate overbank along representative Cross Section 'F' were approximately the same as those simulated for the SWM model, while in the roadway, the combined model flood elevations were 0.2 ft lower than the SWM model (1.2 ft lower than the existing condition).

5.0 CONCLUSIONS

1-dimensional and 2-dimensional modeling of the downtown Ellicott City watershed has provided valuable insight into existing flood patterns of the region and allowed for assessment of the potential mitigation strategies to reduce future flooding from large storm events.

Models were calibrated with anecdotal evidence from the Tropical Storm Lee flooding event and used to simulate the existing flood conditions for large storm events (2-, 5-, 10-, 50-, and 100-yr recurrence intervals and the Tropical Storm Lee event). The results of the existing condition models were then used as baselines to evaluate three flood mitigation scenarios which included stormwater management improvements, conveyance improvements, and improvements combining stormwater management and conveyance concepts.

The results of the proposed concept modeling suggest the greatest reductions in flooding, as measured through flooding extent, flood depths, and flood velocities, would be achieved with the stormwater management pond concepts. The storm drain conveyance options offer only minor improvement in some areas relative to water surface elevations, and show increases in other areas downstream of the improvements, making the storm drain options less desirable. The proposed stormwater pond concepts will offer incremental, though not dramatic, reductions in flood elevations during a historical event like Tropical Storm Lee.

Also part of the study was an examination and assessment of the overall watershed effects of small-scale, SWM design concepts proposed by the Center for Watershed Protection (CWP). The proposed CWP facilities within the focus watershed were catalogued and applied to the existing condition TR-20 model. These facilities were found to have minimal impact on the discharge to the watershed outlet for the 2-yr storm, and thus were not considered as part of flood mitigation strategies for the large storm events targeted in this study.

2012

Case Study: Valley Mede-Ellicott City Tropical Storm Lee Flood Event

Case Study-2011 Valley Mede-Ellicott City Tropical Storm Lee Flood Event

S&S Planning and Design, LLC.

6/28/2012

3.2 Property Zones and Mapping

Information extracted from the *Description of Property Damages* from Interview Form, as well as interviewer notes acquired during property owner interviews is compiled in narrative format and mapping illustrating the flow of flood waters is presented by address zones.

8700 Address Zone
Structures within the 8700 zone were impacted by flooding from the creek and flood waters that escaped the channel and utilized Frederick Road as a flood conveyance. All of the structures within this zone are located on the south side of Frederick Road. Flood waters 'jumped' out of the channel at the Frederick Road Bridge No. 1 as indicated on the map.It is likely that a debris accumulation may have occurred at the upstream edge of the bridge, thereby resulting in or exacerbating the flood waters leaving the channel. Flood waters then flowed east along the northern side of the road, somewhat contained by the road crown and a swale feature on the northern side of the road; however, flood water was continuously cresting the road crown and flowing back toward the actual floodplain and creek channel. The majority of the flood flow then crossed to the south of Frederick Road at a low point immediately west of the Rogers Avenue intersection. The section of Hudson Branch immediately across from the Rogers Avenue intersection consists of a rectangular concrete channel. Observers noted that some flood water continued to flow down Frederick Road.

8600 Address Zone
Structures within the 8600 zone experienced flooding from the creek and what witnesses described as excessive stormwater runoff down Rogers Avenue. A concrete stormwater junction box is located to the northeast of the Rogers Avenue/Frederick Road intersection. Witnesses reported that the manhole access cover was 'blown off' the lid of the box. Additionally, they reported that the concrete top was being elevated. This observation would indicate that the junction box and the stormwater pipes leading to it were at capacity, creating sufficient hydraulic pressure to lift the top and remove the manhole cover. With the stormwater system at capacity, excess stormwater would utilize the roadways as the storm conveyance.

The combined flows from the creek channel/floodplain, Frederick Road, and Rogers Avenue, in conjunction with the low, flat topography of the area, created a large area for floodwater to accumulate. It was reported that the water was over the guardrail of the bridge leading to the small parking lot across from the intersection. Immediately downstream of the intersection, the topography constricts the valley again and the gradient gets steeper. At approximately the middle of this zone, it was reported that the flow depth over the road was estimated at 12-18 inches. The structures immediately adjacent to the creek experienced water in the basements due to the elevated creek levels. The rear of many of these structures terminate at the stacked stone flood wall along the creek, with some structures overhanging the creek, or completely bridging the creek to the far bank.

This zone extends downstream to just beyond the inlet of the large culvert that conveys flow under Frederick Road and several commercial properties. Witnesses reported that floodwaters were overtopping the culvert inlet and continuing down Frederick Road.

It is possible that debris accumulation or blockage at the culvert inlet resulted in flood waters overtopping the culvert headwall and continuing down Frederick Road.

8500 Address Zone

Flooding within the 8500 zone was the result of both flood waters from the creek and roadway. Witnesses reported significant flood flow down Frederick Road. A very large and long culvert conveys flow (9' diameter x 600' length) under Frederick Road and several commercial businesses. Observers stated that during the flood a significant amount of water was flowing down Frederick Road. Some flood flow re-entered the floodplain around property identifier 8560 on both sides of the structure. Downstream of this structure and within the floodplain, a berm had been installed within the last several years. The presence and orientation of this berm redirected flood flow from Frederick Road, thereby preventing flow from returning to the channel. This berm effectively transferred flood flow downstream into an area with additional structures.

An additional culvert is located within this zone. The channel approaching the culvert inlet is armored with gabions in a trapezoidal shape. A preponderance of Japanese Knotweed is located along both banks. An eye witness stated that an approximately 8-10" Red Maple had been leaning diagonally across the culvert inlet during the flood event. Witnesses stated that the inlet was almost completely blocked with debris. Therefore, this culvert inlet also created additional backwater and another location where flood flow 'jumped' from the channel.

Many witnesses to the flood stated that at one point, it appeared as though a 'wall of water' came down the channel. Near Property ID 8500 a small wooden footbridge existed prior to the flood event. An eye witness stated that water and debris was piling up behind this footbridge, then suddenly, one side of the bridge/abutment connection failed and the footbridge swung open like a gate, releasing the backed up water and debris. The rushing water at this location resulted in severe bank erosion, with some streambanks losing 10-12 feet of lateral material. Severe erosion and land loss occurred throughout this reach. Some sections within this zone lost 10-12 feet of streambank.

8400 Address Zone

The 8400 zone did not have any reported damages due to the flooding. One resident indicated that the flood water reached an elevation of the back steps, but did not come into the structure.

8300 Address Zone

The 8300 zone demarcates the beginning of the Downtown Ellicott City section and consists predominantly of commercial properties. At the top end of the zone, the stream outfalls from a large, approximately 400 foot long culvert. This sectionexperienced damages due to the flood event. The flooding was primarily located within the principal channel and floodway area. This stream section is nearly entirely contained within stacked stone or block flood walls. Properties located immediately adjacent to or over the channel experienced basement flooding due to the water elevation cresting over one of the channel walls.In several locations, the southern stacked stone wall and the nearby properties are at a lower elevation, thereby resulting in the reported basement flooding.

Additionally, a channel constriction, or reduction in channel cross-sectional area, within the conveyance under Main Street most likely created backwater conditions through this reach exacerbating the flood elevations.

8200 Address Zone

Only several properties within the 8200 zone reported minor damages due to the flooding.Within this zone, the stream flows between two parking lots; a footbridge connecting the two parking lots was heavily damaged by the flood. One observer stated that flood waters impacting the upstream edge of the bridge sent geysers of water upward to the approximate height of the street lights. The parking lots flooded; however, the flood waters reentered the channel prior to flooding the majority of the first floor businesses located adjacent to the parking lots. A couple of businesses did experience minor flooding that necessitated carpet cleaning and/or removal.

8100 Address Zone

The 8100 zone experienced primarily basement flooding due to the elevated water levels within the primary creek channel. More than fifty percent (50%) of the channel through this zone is bridged by buildings, with stone flood walls on each side of the channel. An unnamed tributary to Tiber Branch confluences with Tiber Branch in this zone.Several properties reported five to six feet of water within the basement. Minor damages were reported, including problems such as general clean-up and HVAC servicing. Several properties reported that water entered through the front door, the result of excess stormwater within the street system.

8000 Address Zone

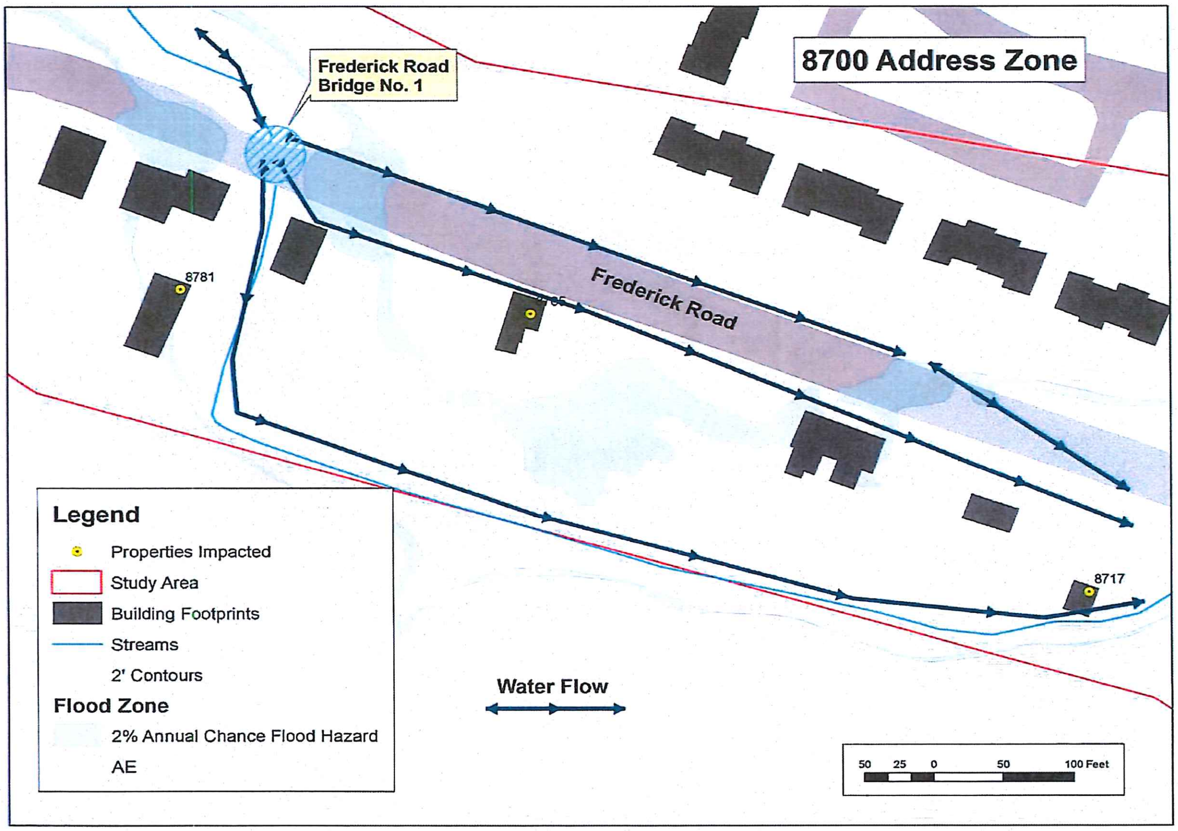
The 8000 zone is the lower end of the downtown section of historic Ellicott City. This zone experienced two types of flooding. The properties on the northern side of Main Street (Frederick Road) experienced excessive stormwater runoff from the steep gradient behind the buildings. The properties on the southern side of Main Street experienced primarily basement flooding due to the elevated water levels in the channel. The majority of Tiber Branch through this zone is bridged by buildings and roadways.

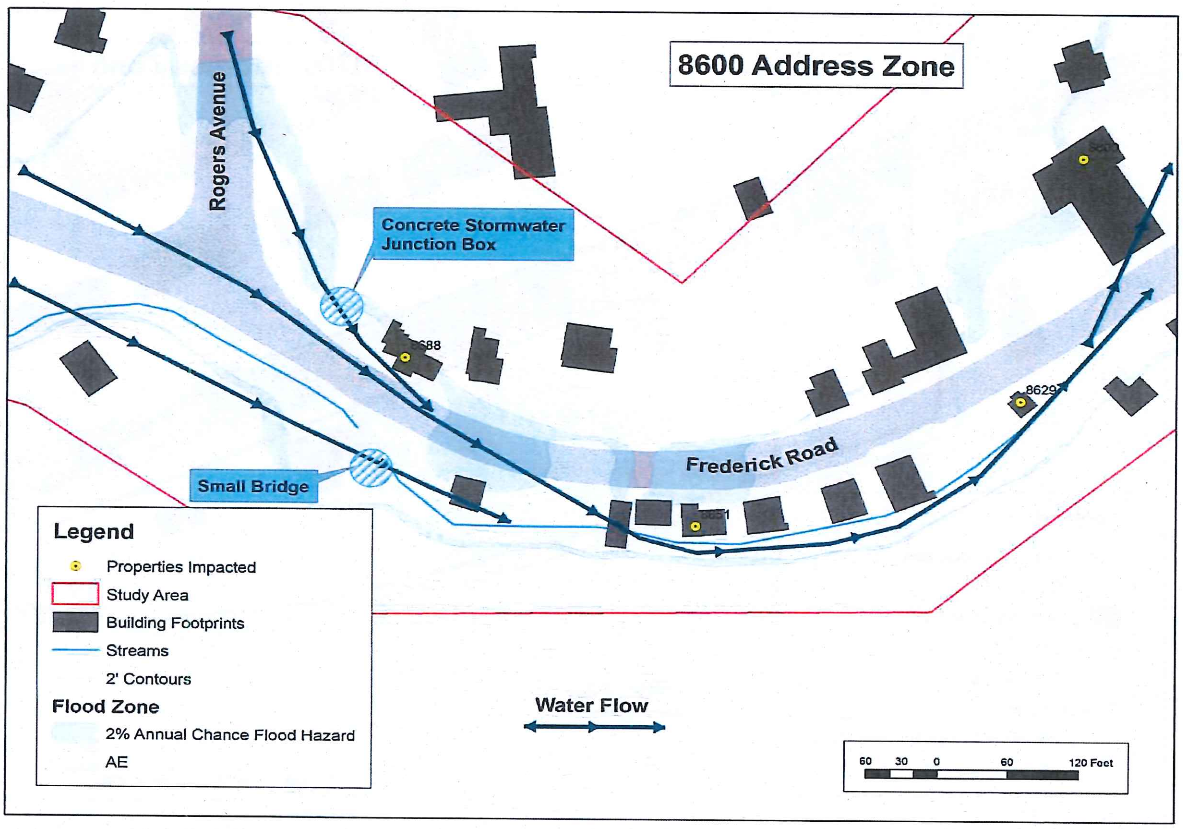
Stormwater runoff from the steep hillside behind the structures situated on the north side of Main Street resulted in flooding issues for some properties. Several properties experienced water seepage through the back wall of the structure. One property experienced a roof collapse; the roof was tied into the hillside and runoff collected on the roof causing the collapse.

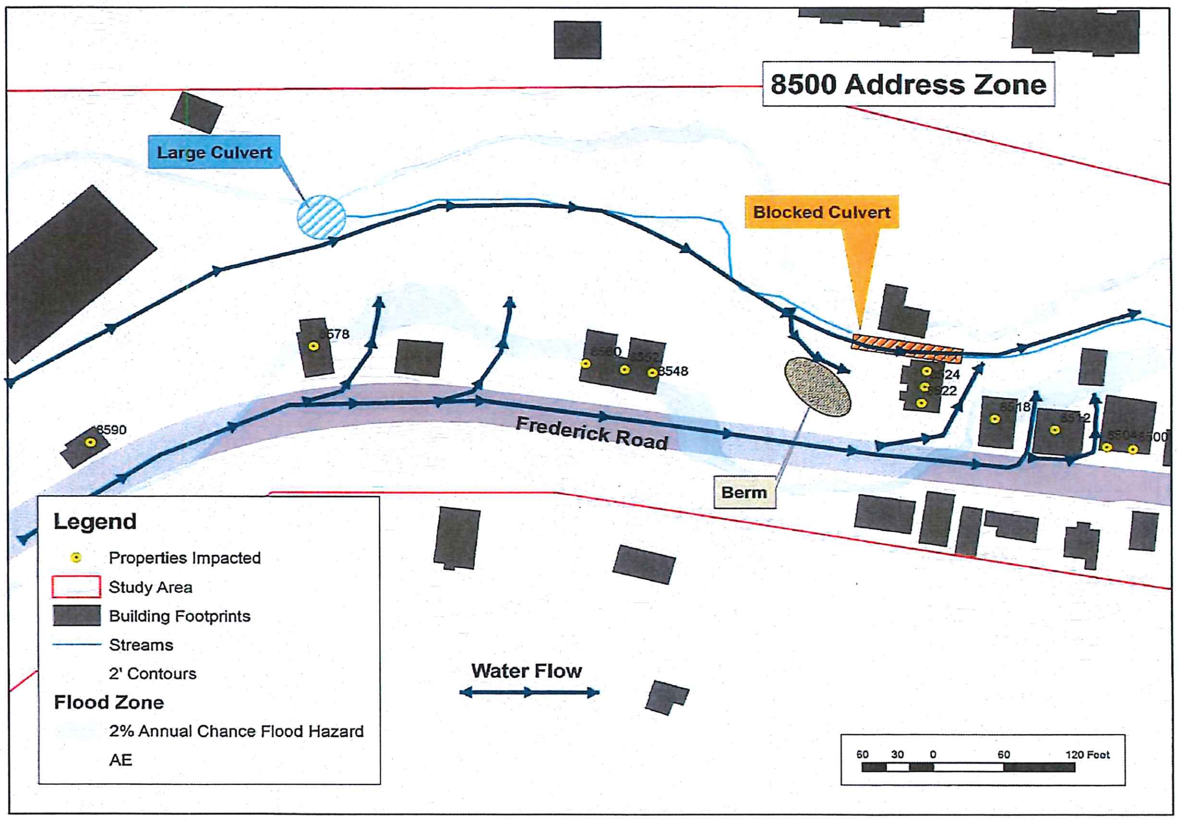
The properties on the south side of Main Street experienced basement flooding; several properties reported basement flooding with depths of four to five feet. Damages ranged from minor to extensive, depending on the location/elevation of the structure, and the contents and utilities located in the basement. One structure reported damage to a walk-in refrigerator, ice machine, hot water heater, plumbing, mortar, floor tile, and the foundation.

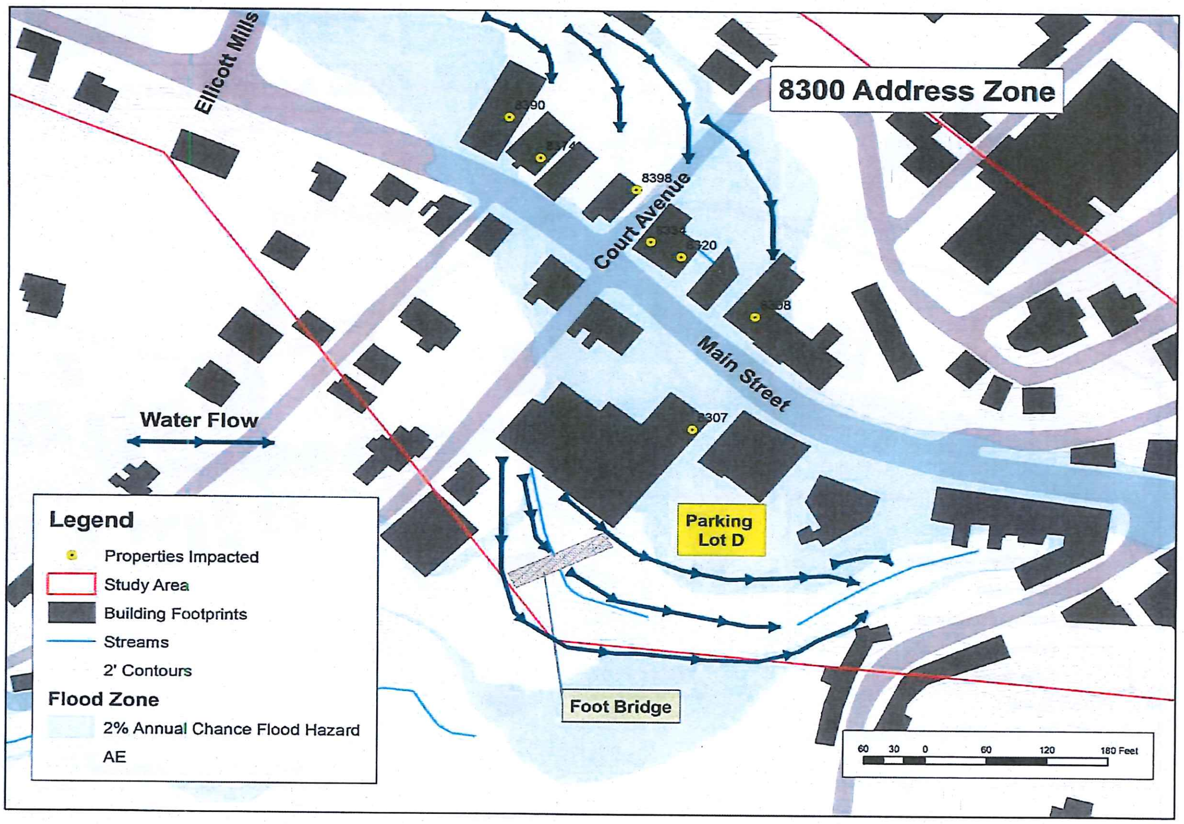
Valley Mede Zone

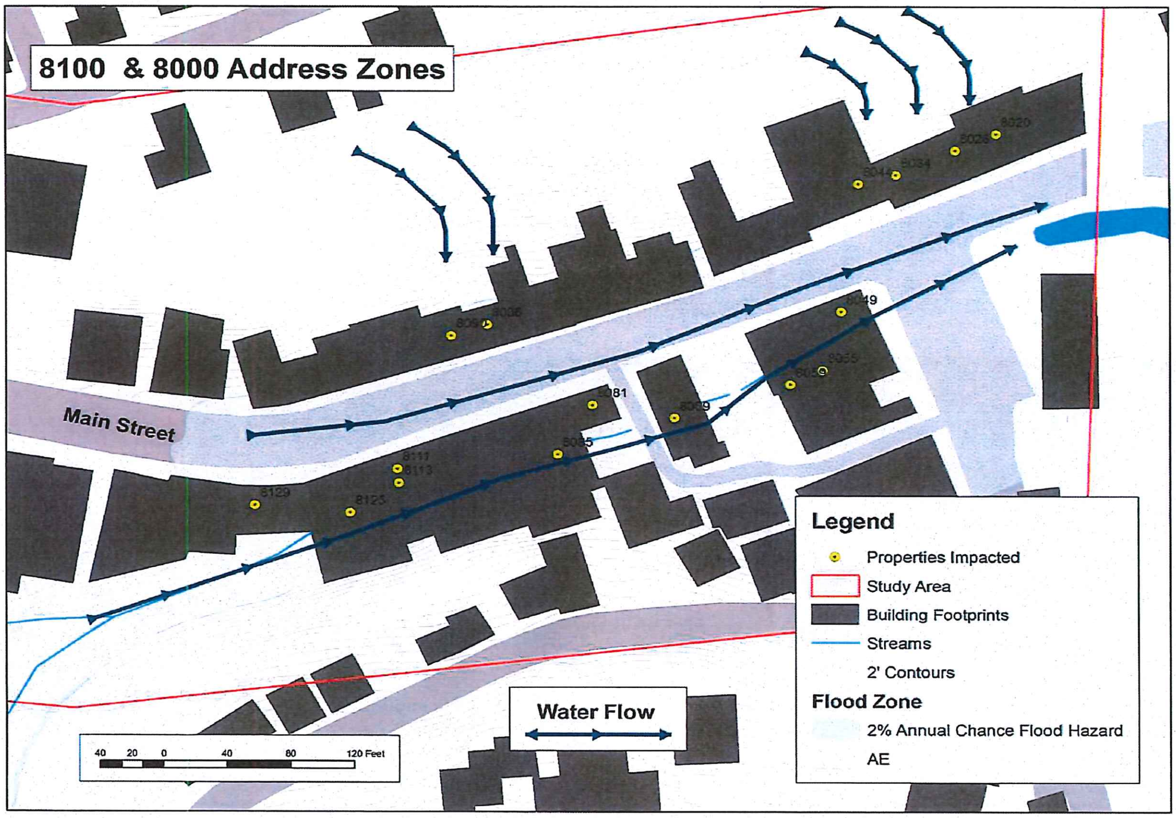
Residential properties adjacent to Plumtree Branch in the Valley Mede subdivision experienced significant flooding and damages. Flood waters rose quickly due to the heavy rainfall in a short duration of time. One resident indicated that within 45 minutes, the flood water increased from cresting the channel banks to being six inches deep in the finished basement. This homeowner also stated that the water did not reach the elevation of the patio during Hurricane Agnes in 1973. One structure in Valley Mede experienced approximately four feet of water in the first floor of the dwelling, rendering the entire home uninhabitable. Culverted road crossings created backwater conditions until the flood breached the road crest. Several property and road wash-outs occurred when the flood water crested the road and re-entered the channel at the downstream culvert location. At one location, the wash-out damaged the utilities for the home, creating a loss of water, electric, and gas for several days.


8700 Address Zone
Frederick Road Bridge No. 1
Frederick Road
8781
8717
Legend
Properties Impacted
Study Area
Building Footprints
Streams
2' Contours
Flood Zone
2% Annual Chance Flood Hazard
AE
Water Flow
50 25 0 50 100 Feet


8600 Address Zone
Rogers Avenue
Concrete Stormwater Junction Box
Small Bridge
Frederick Road
8629
Legend
Properties Impacted
Study Area
Building Footprints
Streams
2' Contours
Flood Zone
2% Annual Chance Flood Hazard
AE
Water Flow
60 30 0 60 120 Feet


8500 Address Zone
Large Culvert
Blocked Culvert
Berm
Frederick Road
Water Flow
Legend
Properties Impacted
Study Area
Building Footprints
Streams
2' Contours
Flood Zone
2% Annual Chance Flood Hazard
AE
60 30 0 60 120 Feet


8300 Address Zone
Ellicott Mills
Court Avenue
Main Street
8398
8307
Water Flow
Parking Lot D
Foot Bridge
Legend
Properties Impacted
Study Area
Building Footprints
Streams
2' Contours
Flood Zone
2% Annual Chance Flood Hazard
AE
60 30 0 60 120 180 Feet


8100 & 8000 Address Zones
Main Street
8020
8026
8034
8044
8049
8081
8111
8113
8125
8129
Legend
Properties Impacted
Study Area
Building Footprints
Streams
2' Contours
Flood Zone
2% Annual Chance Flood Hazard
AE
Water Flow
40 20 0 40 80 120 Feet

2016
Ellicott City Hydrology/Hydraulic Study
and Concept Mitigation Analysis

McCormick Taylor Project No. 5519-93
June 16, 2017

Prepared for:
Howard County Government
Storm Water Management Division
Bureau of Environmental Services
6751 Columbia Gateway Drive, Suite 514
Columbia, Maryland 21046-3143

Prepared by

McCORMICK TAYLOR

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buildings as noted above, results in 6'-8'+ of flooding through this stretch between Caplan's and the Phoenix Emporium (8137 to 8049). Video at the peak of the July 30, 2016 storm indicated flows nearly touching the bottom of the store awnings in this area, supporting the calculations of the model.

As the flow of the combined three subwatersheds continues in the channel beneath buildings, through Tiber Park, and under the B&O Railroad Bridge, as well as down Main St., the inundation of the two flow paths reconnects them through this last stretch prior to combining with the Patapsco River. In looking at the subsequent improvement strategies for conveyance and stormwater management, this area will prove to be the most challenging to return to a manageable depth for the 100-year and similar storm events due to the flat grade, full watershed contribution and lack of a floodplain in the confined channel under several structures.

4.0 Conceptual Improvements

This study focused on two main types of conceptual improvements, stormwater quantity management (SWM) to reduce the quantity of flow into the Frederick Rd./Main St. corridor, and conveyance improvements that would upgrade or supplement the storm drains and channels through the flooded area to carry more water at a lower elevation for a given event. The structure of the model created for this study allows for any variation on, or combination of, improvements to be run through the model as part of a larger long-term planning effort, however for the sake of keeping the large amount of data manageable, the focus of this study looks at a progressively cumulative improvement using four types of approaches in total, and subsequently examines an incremental improvement considering selected individual improvements as defined below. The alternative of retrofitting the existing SWM facilities in the watershed is also examined relative to the other options presented below.

The approach to determining how much SWM storage is necessary to effectively reduce flood elevations and the probability of damaging flooding was based on attempting to store as much of the volume as possible that makes up the difference between the 10- and 100-year events, in order to reduce the peak flow of the 100-year event down to that of the 10-year event. This required temporary storage in the form of ponds as well as underground SWM. The effectiveness of each in reducing peak flow can be seen in *Figures 4.1* through *4.3* below.

For the SWM ponds, all in-line ponds assumed allowance for the 5-year storm event to pass through before accumulating meaningful storage. This is based on the premise that the downstream channels can accommodate this storm event, and that the meaningful storage could then be reserved for the higher storm events. This is also allows for the branches to maintain their existing base flows, and not changing the appearance of the stream running through downtown. Volume was maximized based on available undeveloped area with emergency spillways routing the higher storm events where necessary. During the large storm events, excess runoff would be temporarily stored within the facilities and let out at a controlled rate. At the time of this report, the County has initiated preliminary discussions with the Maryland Department of the Environment (MDE) regarding the in-line nature of the ponds as well as the likelihood of high hazard dams that will require Emergency Action Plans for downstream areas.

Figure 4.1: Peak Flow and Volume, 10- and 100-Year Storm.

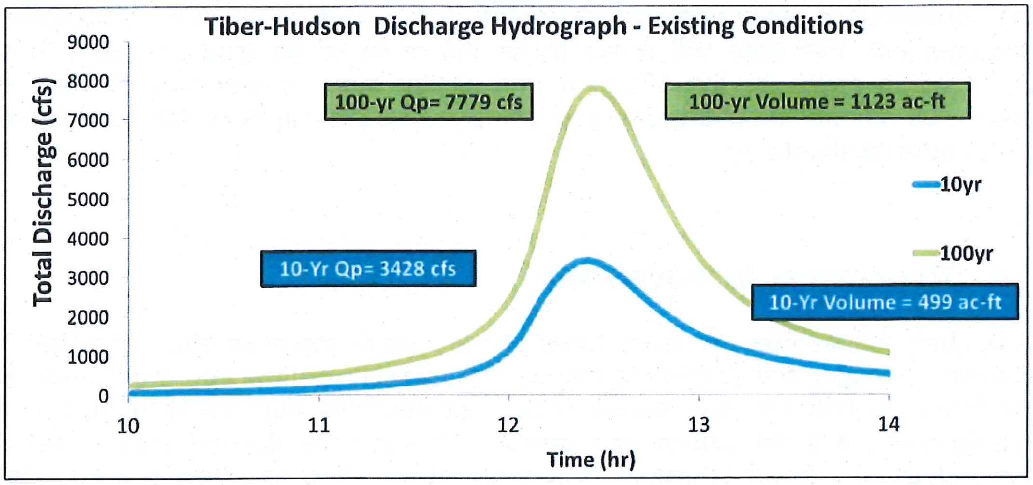


Figure 4.2: Peak Flow and Volume, 10- and 100-Year Storm.

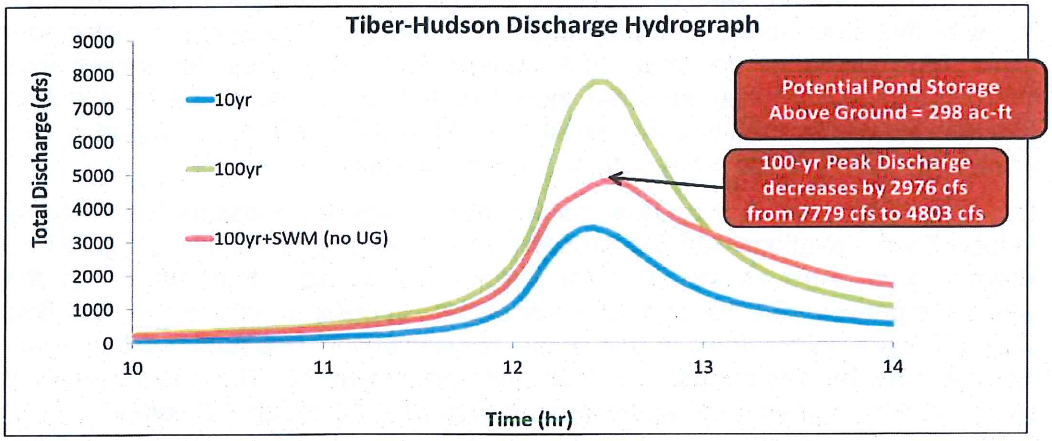
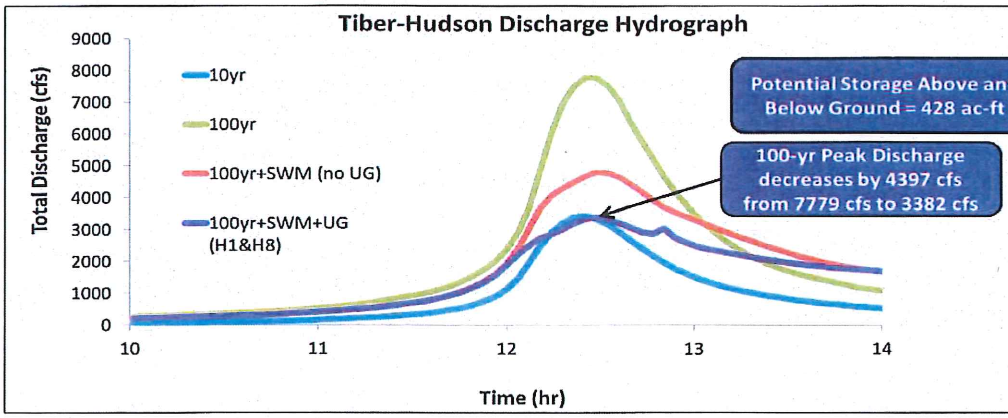


Figure 4.3: Reduction in Peak By Storage, Above and Below Ground SWM



For underground SWM areas, two approaches were considered: underground pipe storage, aka 'pipe farms' which would exist offline, storing diverted flow up to maximum capacity and outletting metered flow by gravity; and underground vaults, which are concrete storage spaces that store diverted excess flow from the channel and drain utilizing pumps over the course of 2-3 days following the storm event. All SWM facility conceptual layouts and grading maps can be found in *Appendix B.*

Capacity improvements examined include supplemental cross culverts where the Hudson Branch crosses the roadway, which are generally only effective at reducing flooding in their local vicinity; bypass culverts which supplement existing culverts carrying Hudson Branch and have effectiveness in reducing flooding in portions of the West End; and tunnels bored through existing rock under adjacent highlands and buildings to carry excess flow underground and divert it away from Lower Main St. Maps of conceptual conveyance improvements are found in *Appendix B.*

4.1 TIBER BRANCH

Improvements in the Tiber Branch focused on a single, large in-line SWM pond (T1), approximately 70 acre-feet in storage size. This was chosen as it was feasible within a wider, undeveloped area of the floodplain without excessive excavation relative to the volume of storage; and also because its size in this smaller subwatershed makes it particularly effective at reducing the peak flows out of this subwatershed. This would likely be a high-hazard dam. Additional details are noted in *Table 4.1.*

4.2 NEW CUT BRANCH

Improvements in this subwatershed included the examination of several in-line SWM ponds which attempted to maximize available undeveloped floodplain area for storage. From that initial set, there was a notable drop off in the effectiveness of the sites below a certain volume threshold of about 12 acre-feet, so going forward the four largest, most effective ponds were chosen for the concept modeling. Three of these ponds (NC1-NC3) were in-line within the Autumn Hill tributary, with the upstream-most pond being the most effective when examined individually. The downstream-most pond of the three, because of its location, which does not have an emergency spillway location, would likely need to be constructed as a concrete dam. All three ponds would likely be high-hazard dams. The fourth (NC-4) is near the headwaters of New Cut in the southeast corner of the watershed, and is the smallest and least effective of the four when examined individually.

4.3 Hudson Branch

The Hudson Branch subwatershed was the most challenging one to find locations for the large in-line SWM ponds that were so effective in reducing peaks within the other two subwatersheds, largely because of the development adjacent to the floodplain, which is denser and more commercial than the other subwatersheds, and also because this branch is very much intertwined with Frederick Rd./Main St. in its lower reaches. Because all of the meaningful flooding takes place within this branch, before and after its confluences, this is where the majority of the improvements are conceptually proposed and examined.

4.3.1 Stormwater Ponds

Conceptual improvements include three SWM ponds in-line and off-line within the US 40 / US 29 interchange (H5-H7), which is owned by Maryland State Highway Administration (MSHA) as well as three additional ponds adjacent to or within the Hudson Branch (H2-H4), with all but one (H2) upstream of US 29 at Frederick Rd. The pond in the NW loop ramp of the interchange (H7) which is online, is the most effective in this subwatershed when examined individually; the pond in the opposite NE loop ramp (H6) which is offline, the least effective of the six.

4.3.2 Underground SWM

Conceptual Improvements include pipe farms and vaults as defined above. The pipe farm in the old Roger Carter Center property above Lot 'F' on Ellicott Mills Dr. (H8-UG1) includes ~4600 LF of 10' diameter pipe. The additional 3 sites (H8-UG2-4) are located west of US 29 in the undeveloped strip of land currently owned by BGE for their high tension power lines. These pipe farms would comprise ~3.3 miles of 10' diameter pipe located near but not in the footprint of the current towers. The total storage of these 4 sites is approximately 40 acre-feet. At the time of this report, BGE has not been contacted by the County to discuss specific locations for use of their Right-of-Way.

There are three concrete vault locations (H1-UG1-3) along the Hudson Branch east of US 29 which combined offer up to 90 acre-feet of storage, and, when used in conjunction with the pipe farm facilities (H8) are effective in significantly reducing the peak flows in this subwatershed. The locations are at Lot 'F', the current West End Service site and the areas between residential structures at 8777-8729 Frederick Rd. These sites represent conceptual storage of volume divided up based on footprint, but in fact their relative sizes and locations could vary depending on subsurface conditions (which may allow easier, deeper excavation, at one site vs another) with their overall effectiveness varying little, so long as the quantity of storage remains the same.

Table 4.1 and 4.2 indicate the volume and reduction in flow resulting from each of the individual SWM alternatives, as well as combined for the subwatersheds.

Table 4.1: Peak Flow Reduction Per Facility and Combined, Tiber Branch and New Cut Branch Watersheds

Tiber Proposed SWM				
	Total Without Concept Management		Total With Concept Management	
	Q10	Q100	Q10	Q100
T1 (Tiber)	497	1078	168	334

Tiber Concept Ponds Treatement Summary	
	Tiber
	T1
Storage	70.0 ac-ft
Emb. Height	24 ft
Change to Q100 - Total Tiber 100YR	-69%

New Cut Proposed SWM				
	Total Without Concept Management		Total With Concept Management	
	Q10	Q100	Q10	Q100
NC1 (New Cut)	1640	3581	1630	3053
NC2 (New Cut)	1640	3581	1396	3052
NC3 (New Cut)	1640	3581	1241	2876
NC4 (New Cut)	1640	3581	1462	3420
Total Combined	**1640**	**3581**	**965**	**2464**

New Cut Concept Ponds Treatment Summary					
	New Cut				Combined New Cut Concepts
	NC1	NC2	NC3	NC4	
Storage	34.0 ac-ft	42.0 ac-ft	63.0 ac-ft	14.4 ac-ft	153.4 ac-ft
Emb. Height	28 ft	18 ft	21 ft	11 ft	
Change to Q100 - Total New Cut 100Y	-15%	-15%	-20%	-4%	-31%

Table 4.2: Peak Flow Reduction Per Facility and Combined, Hudson Branch Watershed

Hudson Proposed SWM				
	Total Without Concept Management		Total With Concept Management	
	Q10	Q100	Q10	Q100
H1 - UG (Hudson)	1203	2907	734	2613
H2 (Hudson)	1203	2907	1124	2821
H3 (Hudson)	1203	2907	1162	2864
H4 (Hudson)	1203	2907	955	2663
H5 (Hudson)	1203	2907	1128	2798
H6 (Hudson)	1203	2907	1161	2823
H7 (Hudson)	1203	2907	1129	2598
H8 (Hudson) BGE/RGR CRTR	1203	2907	903	2459
Total Combined	**1203**	**2907**	**669**	**752**

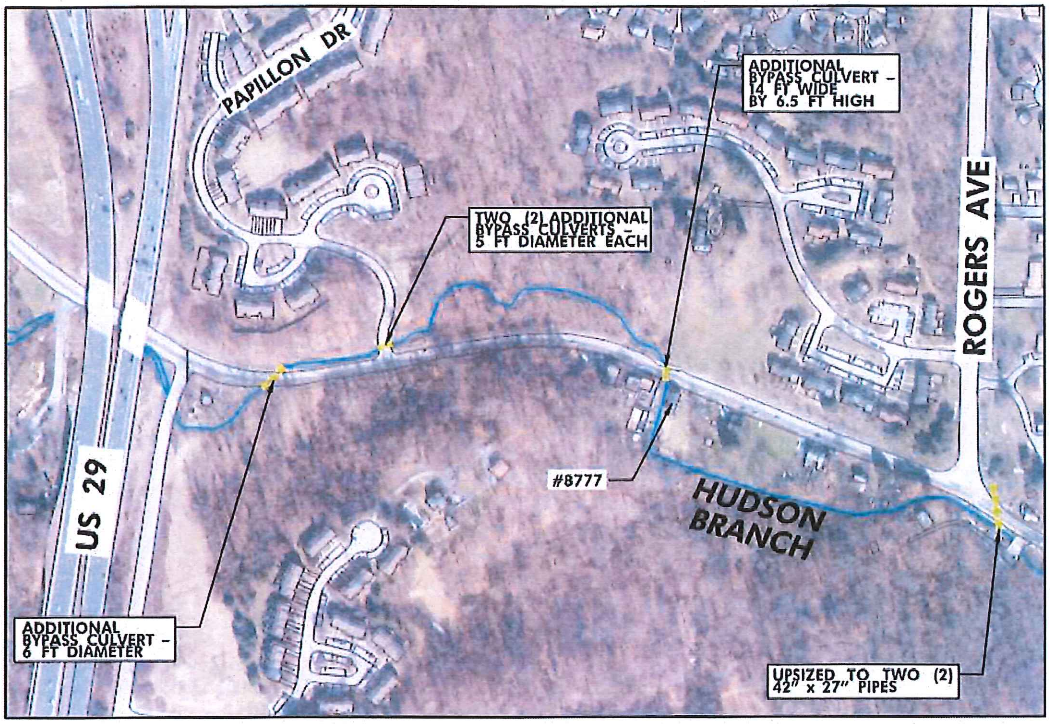
Hudson Concept Ponds Treatment Summary									
	Hudson Branch								Combined Hudson Concepts
	H1-UG 1-3	H2	H3	H4	H5	H6	H7	H8-UG 1-4	
Storage	82.4 ac-ft	15.0 ac-ft	7.7 ac-ft	15.6 ac-ft	11.5 ac-ft	12.0 ac-ft	12.8 ac-ft	40.0 ac-ft	197.0 ac-ft
Emb. Height	N/A	15 ft	11 ft	9 ft	12 ft	14 ft	12 ft		
Change to Q100 - Total Hudson 100YR	-10%	-3%	-1%	-8%	-4%	-3%	-11%	-11%	-74%

4.4 CONVEYANCE IMPROVEMENTS

Conceptual improvements to the capacity of pipe and culvert systems along Frederick Rd./Main St. include supplemental cross culverts added to the model in the following locations:

- 8800 Frederick Rd. – Additional 6' culvert
- Papillon Dr. – 2 Additional 5' culverts
- 8777 Frederick Rd. – Additional 6.5' x 14' box culvert
- 8680 Frederick Rd. @ Rogers Ave. - 2 – 42" x 27" pipes – This carries flow from Rogers Ave. across the road into channel

Figure 4.4: Supplemental Cross Culvert Locations

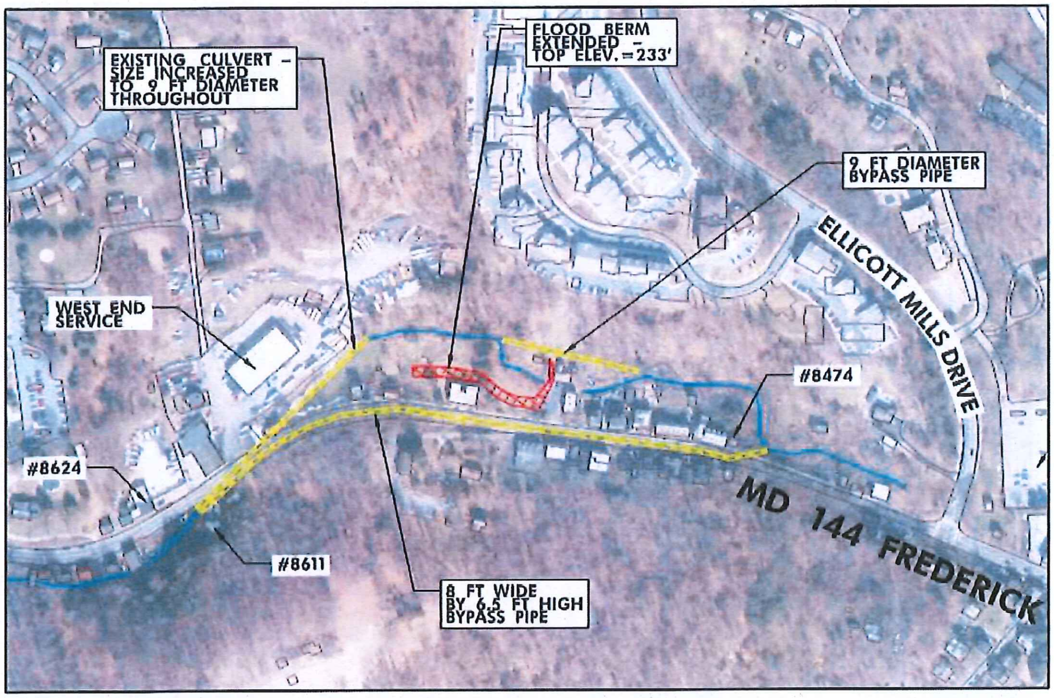


To address the capacity issue at the existing 108"/88" culvert at 8611 Frederick Rd., the model includes the following conceptual improvements:

- Restore the existing culvert to 108" diameter throughout and add a supplemental 6' x 8.5' culvert along the roadway to carry additional flow to an outfall into the channel downstream of 8470

- 8532/34 Frederick Rd.: add a 9' bypass culvert to carry flow behind the houses at 8532 where constricted by the existing culvert, and combine with a flood berm from spanning from 8572 to 8534 to protect adjacent houses from floodplain flow.

Figure 4.5: Supplemental Bypass Culvert Locations



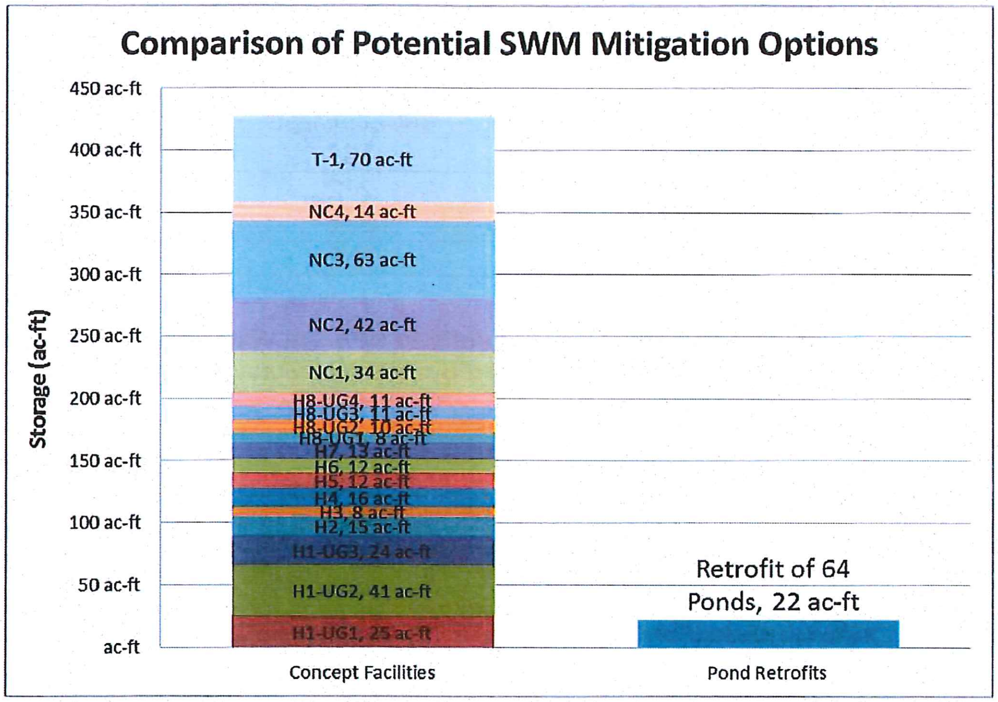
The effects of the capacity improvements on the hydraulic models are shown in more detail and discussed in Section 4.7 below. Larger maps of the options can be found in *Appendix B*; modeling in *Appendix D.*

4.5 Examination of Retrofit of Existing SWM Facilities

The analysis considered what the impacts would be on retrofitting the existing 64 SWM facilities throughout the watershed relative to the larger scale SWM improvements noted above. The existing ponds account for about 85 acre-feet of available dry storage combined. Considering a rough assumption that, based on constrictions of adjacent development, right-of-way, natural resources, etc., each facility could be increased by about 25% on average, that would yield approximately 22 additional acre-feet storage.

Relative to the changes observed from the creation of 18 new facilities for 428 acre-feet of additional storage, the approach of retrofitting all 64 existing SWM facilities did not warrant further modeling based on the effective change per each of the 64 individual projects (~1/3 acre-foot per site, on average). A relative scale of this option can be seen in *Figure 4.6*, below.

Figure 4.6: Existing Retrofit Comparison to Conceptual Improvements



4.6 Flow Reduction From SWM Improvements

As discussed, the stormwater management improvements both above and below ground, provide substantial attenuation of the peak flows, resulting in reduced peak discharges into the 2-D hydraulic model. Provided below is a summary of SWM simulated changes in peak flows from the three subwatersheds (*Tables 4.3-4.5*) as well as change in peak flow at the outlet of the 2-D hydraulic model. The discharges summarized for the three subwatersheds were pulled directly from the hydrograph output by the TR-20 hydrologic model. The peak flows in *Table 4.6* reflect the combined peak of all inflow hydrographs for the hydraulic model, assuming all conceptual improvements are constructed.

Table 4.3 – TR-20 Simulated Peak Flowrate to Hudson Branch Watershed Outlet for Existing Conditions and the Proposed Stormwater Management Concept

Storm Event	*Peak Flowrate (cfs)*				
	Existing Conditions	*Proposed Above Ground SWM Concepts*	*Percent Change*	*Proposed Above & Below Ground SWM Concepts*	*Percent Change*
10-yr	1203	743	-38%	699	-42%
25-yr	1768	1116	-37%	730	-59%
100-yr	2907	2010	-31%	752	-74%
July 30, 2016	3549	2517	-29%	1396	-61%

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Table 4.4 – TR-20 Simulated Peak Flowrate to Tiber Branch Watershed Outlet for Existing Conditions and the Proposed Stormwater Management Concept

Storm Event	*Peak Flowrate (cfs)*		
	Existing Conditions	*Proposed Above Ground SWM Concepts*	*Percent Change*
10-yr	497	168	-66%
25-yr	734	212	-71%
100-yr	1078	334	-69%
July 30, 2016	1169	438	-63%

Table 4.5 – TR-20 Simulated Peak Flowrate to New Cut Watershed Outlet for Existing Conditions and the Proposed Stormwater Management Concept

Storm Event	*Peak Flowrate (cfs)*		
	Existing Conditions	*Proposed Above Ground SWM Concepts*	*Percent Change*
10-yr	1640	965	-41%
25-yr	2330	1411	-39%
100-yr	3581	2464	-31%
July 30, 2016	3967	2519	-37%

Table 4.6 – TR-20 Simulated Peak Flowrate to Hudson-Tiber-New Cut (Tiber-Hudson Branch) Outlet for Existing Conditions and the Proposed Stormwater Management Concept

Storm Event	*Peak Flowrate (cfs)*				
	Existing Conditions	*Proposed Above Ground SWM Concepts*	*Percent Change*	*Proposed Above & Below Ground SWM Concepts*	*Percent Change*
10-yr	3428	1828	-47%	1801	-47%
25-yr	4947	2716	-45%	2511	-49%
100-yr	7779	4804	-38%	3382	-57%
July 30, 2016	8669	5503	-37%	3455	-60%

The reduced flowrates under the proposed scenario resulted in decreased water surface elevations, flow velocities and the extent of the floodplain; the magnitude of the changes to these variables is dependent on the unique topographic features at any specific cross section in the modeled area. *It is important to note that percent peak flowrate reductions do not necessarily represent equivalent reductions in water surface elevation, flow velocity, or flood extent.*

4.7 Modeling Results of Proposed Improvements

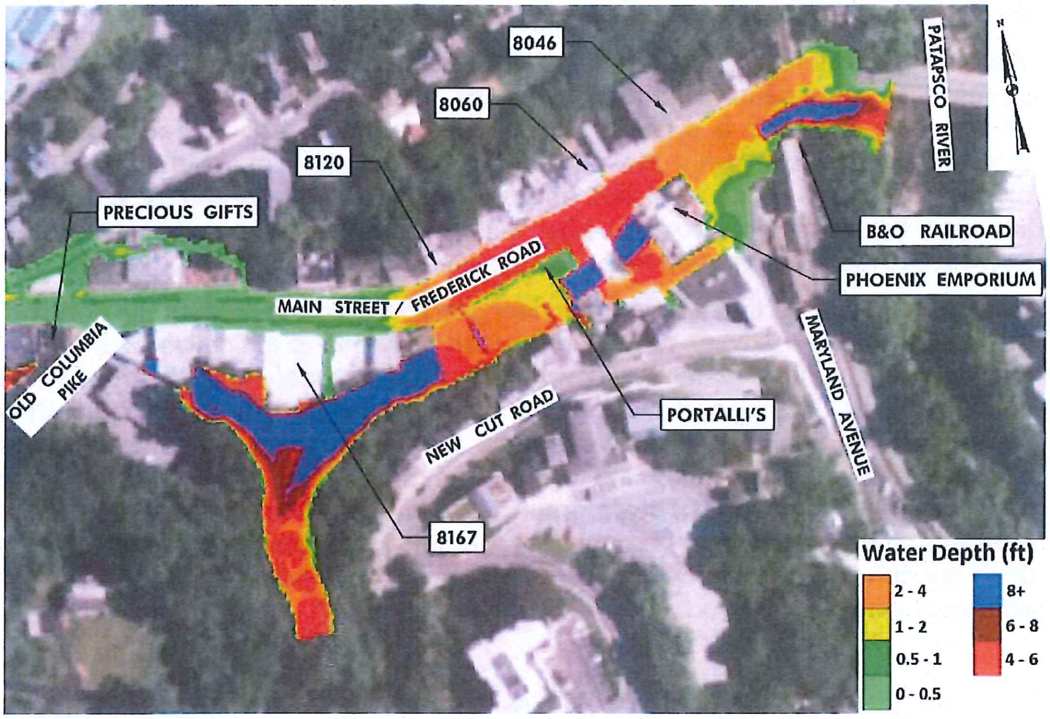
Water surface elevations, and extent of flooding, are reduced incrementally as stormwater management and conveyance improvements are progressively introduced. Below is a summary of the effect of the 428 acre-feet of SWM storage, and subsequently the addition of conveyance improvements, to the existing conditions models detailed above. Additional, larger graphics, which also include a breakdown of flood modeling results between above and below ground SWM improvements, may be found in *Appendix D*

It's important to note that where the model graphics below represent "no flooding" (no color) on the roadway or adjacent areas, that this is indicative of *a lack of flooding resulting from water overflowing out of the channel or overburdened pipe structures only*. This does NOT mean there would be no flow or water depth in the area during this storm event, but rather that the model does not account for all runoff initiated in the immediate vicinity. The model considers the flow directed to the channel from the 10 hydrograph input points within the model and the handling of the major flow 'through' the Frederick Rd./Main St. community. It does not consider the hyper-local runoff between those points that may result in additional minor, local flooding.

4.7.1 Area 1 – US 29 to Rogers Ave.

The roadway flooding at the first point the stream crosses Frederick Rd. just east of Toll House Rd. in the 8800 Block is reduced to under 1' deep, and down below 2' deep at the second crossing of the stream under Papillion Drive. This is a decrease of 1'+. The addition of the supplemental cross culverts at these first two locations further reduces the roadway flooding to about 6" deep.

At the next stream crossing, southward under Frederick Rd. near 8789-77, flooding is reduced below 1' under both scenarios. Flooding of the residential areas on the south side of the roadway is also reduced from 8777 east to the Rogers Ave. intersection, with areas of 2'-4' of flooding now reduced in extent, and in depth down to 0.5'-2', though there are some localized increases at the outlet of the supplemental culvert at 8777. At this culvert it appears either the conveyance or SWM improvement will result in these improvements, but combined they do not provide a significant additional benefit in the immediate vicinity. This is similar with the flooding of the roadway approaching Rogers Ave., which is reduced from 2'+ down to 0.5' to 1' near the roadway edges.

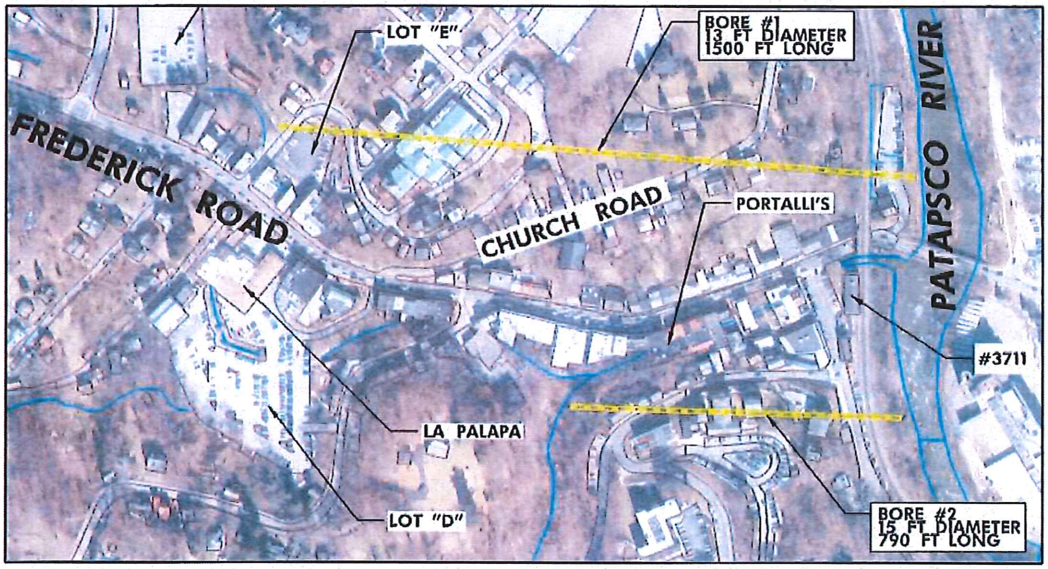


for this storm event by 2'-3'+ however, there is still a section of 4'-6' deep water that is not fully managed through this block. This area still showing over 1' of flooding also coincides with the 100-year flood backwater (elevation 133') from the Patapsco River. It is notable that this model considers flood events that generate from intense rainfall within the Tiber-Hudson watershed (3.7 mi.^{2} which is 1.3% of the 294 mi^2 Patapsco River watershed). In the event of a Patapsco River backwater flooding event (similar to T.S. Agnes in 1972) the proposed concepts will not be effective in reducing flooding from the backwater in this area, though areas upstream of the backwater will experience the reductions modeled here.

4.7.5 Tunnel Bore Improvements

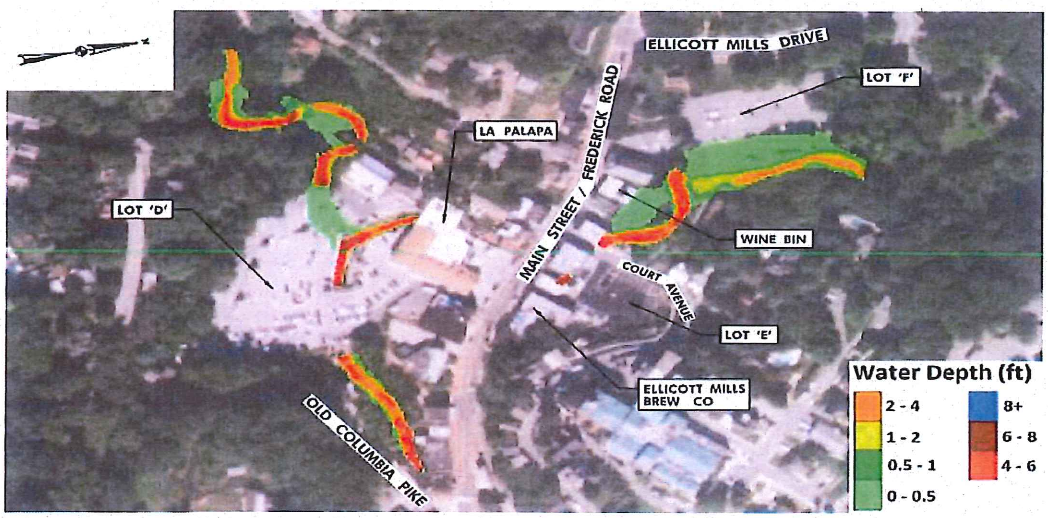
In order to consider a conceptual option that would provide full flood relief for the lower Main St. section for a 100-year event with all of the other SWM conceptual improvements in place, and to address requests made at the inception of this study from the community, the hydraulic analysis examined the concept of tunnels that would bore through the bedrock of Ellicott City in two locations to divert excess flood flows around the Main St. commercial district. Both were located in areas where the terrain goes up very steeply such that the bore would go well beneath any existing structures in the community. The first tunnel would begin upstream of Lot 'E' and would divert flood flows to the Patapsco River approximately 1300' away with a 13' diameter circular bore. The second tunnel, a 15' diameter circular bore, would capture flood flows from the New Cut Branch just upstream of its confluence with Tiber-Hudson and divert through the adjacent hillside to the Patapsco River approximately 790' away.

Figure 4.11: Location of Conceptual Tunnel Bores to Divert Flow around Main St.



The tunnel bores were sized to convey adequate flood flows such that the channel that runs under the buildings on the south side of Main St. would not overflow and flood the adjacent buildings and roadway. The resulting change in the 100-year flooding from channel capacity can be seen for Areas 3 and 4, in *Figure 4.12*. The implementation of such a system would have several challenges relative to the construction, permitting and funding of the tunnels.

Figure 4.12: Flood Area Maps of Area 3 (below) and 4 (next page) w/ Tunnel Bores



5.0 CONCLUSIONS AND RECOMMENDATIONS

The creation of a comprehensive hydrologic and 2-D hydraulic model of the Tiber-Hudson Branch along Frederick Rd. / Main St. east of US 29 provides Howard County with an interactive tool for long term planning and execution of strategies to reduce the probability and severity of flooding in Ellicott City. The results of this study demonstrate that construction of stormwater storage facilities throughout the watershed, combined with stormwater conveyance infrastructure improvements, can make an appreciable difference in the severity of flooding from a 100-year or other similar storm event. However, the nature and scope of such improvements is significant in scope, impact and cost. It will require a long term planning and implementation effort, supplemental to the Master Plan process, to prioritize, design and construct improvements based on the concepts represented in this report. In the shorter term, flood proofing and insurance of buildings and their contents within the floodplain should be a consideration throughout the study area.

In the interest of representing what a subset of selected improvements, of the type that would hypothetically represent the first stage of a multi-stage plan, would result in, the analysis included modeling of a subset of improvements. These SWM improvements were chosen for the subset based on their having the greatest individual impact on their respective subwatersheds in terms of peak flow reduction (see *Sections 4.1-4.3* and *Tables 4.1, 4.2*) and included T1, NC3 and H7 (ponds) and additionally H8 (Underground Pipe Farms) along with the proposed conveyance improvements (not including the tunnel bores). The mapping demonstrating the flooding reductions associated with this subset of improvements may be found in *Appendix E.*

It should be noted that these concepts, particularly those representing stormwater management and storage, are broad-brush representations of practices that can significantly vary in their final detail and location while still achieving the same improvements. The dynamic nature of the model will allow for the continued analysis of chosen alternatives as they are refined in the planning and design of future improvements associated with Ellicott City flood mitigation.